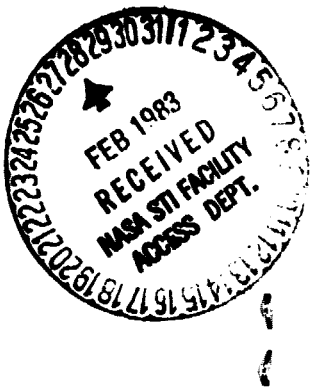
(NASA-CR-169898) SOLAR DIAMETER MEASUREMENTS FOR STUDY OF SUN CLIMATE COUPLING Final Report, Jun. 1981 Nov. 1982 (Arizona Univ., Tucson.) 10 p HC A02/MF A01 CSCL 04B G3/47

N83-19390

Unclas 08745

SOLAR DIAMETER MEASUREMENTS FOR STUDY OF SUN CLIMATE COUPLING

Henry A. Hill
Department of Physics
University of Arizona
Tucson, Arizona 85721



January 1983
Final Report for Period June 1981 through November 1982

Grant NAG 5-143

Prepared for

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

Preface

This project was initiated to detect changes in solar shape and diameter as a possible probe of an important climatic driving function, variability in the solar luminosity. These changes are to be monitored using the techniques and facilities developed at SCLERA[1] during the 1970's for measuring the solar diameter. During the contract period, this project's observing program on the SCLERA instrument was continued, as was the requisite data reduction. A technique has been designed which will allow the calibration of the telescope field, providing a scale for long-term comparison of these and future measurements; construction of this device has begun.

[1]SCLERA is an acronym for the Santa Catalina Laboratory for Experimental Relativity by Astrometry, a facility jointly operated by Wesleyan University and the University of Arizona.

Table of Contents

1. Introduction

Many researchers have attempted to detect and monitor climatically significant changes in the solar constant (for review, see White 1977; Pepin, Eddy and Merrill 1980; Sofia et al. 1979; Gough 1980; Kandel 1981). One indirect diagnostic of luminosity variability utilizes changes in the solar shape and diameter. Because of the advances made at SCLERA during the 1970's in the accurate measurement of solar diameters, studies of this type may offer a more sensitive and cost-effective probe than direct measurements.

Improvements in solar diameter measurements have been made possible by an astrometric telescope designed solely for work relating to the sun and by the introduction of a new technique for the definition of an edge on the solar limb. Oleson et al. (1974) give a description of the telescope used in SCLERA's work; discussions of the edge definition may be found in papers by Hill, Stebbins and Oleson (1975) and Hill (1978).

A program to monitor the diameter and shape of the sun as an indirect diagnostic of the solar luminosity is ongoing at SCLERA. During the period of 1 June 1981 through 30 November 1982, this program was partially supported by NASA contract NAG5-143. In the following report we will summarize the work completed and the problems encountered under this contract.

2. Summary of Work Performed

At the beginning of the contract period, observations of the solar diameter were in progress. As discussed in previous reports (Hill 1981), the telescope detectors were operating in a "frozen" mode (i.e., no change or alterations), allowing the measurement of day-to-day

changes in the solar shape. The primary measuring engine was a combined phase-encoded Michelson He-Ne laser and double pass white light interferometer, the latter producing a zero-point fiducial for the former.

Only thirteen acceptable daily data segments were acquired over a 41-day period which commenced before the contract starting date. The seasonal rains and thunderstorms which prevail in the Southwest began during the latter part of June. However, the year previous to this had seen long patterns of exceptional cloudiness unusual for this area. Weather during the summer of 1981 continued this trend, with severe lightning storms in the mountains and around the SCLERA telescope site. Unfortunately, during August of 1981 several surges passed through the existing lightning protection, severely damaging the telescope computer system and electronics. For the remainder of the contract period, the activity at the telescope site centered around efforts to restore the old system and, finally, its complete replacement with a new computer system. New and more thorough lightning protection has been installed at the site to prevent accidents of this type from recurring.

Although no new data were taken after the storm damage, the analysis of the existing 1981 data has proceeded to the preliminary level. These new results were presented at the XVIII General Assembly of the International Astronomical Union in August 1982 (Caudell et al. 1982); the associated abstract is included as an Appendix in this report. Briefly, this data consisted of thirteen daily time strings of solar diameters, measured cyclically at seven position angles on the solar disk, with each string lasting from four to six hours. After the larger systematic errors were modeled and removed and the white light interferometer fiducial incorporated, each daily string was averaged over

position angle and time to produce a mean daily solar diameter. When this mean was plotted versus calendar date, the gross signature of the variation in the earth-sun distance due to the eccentricity of the earth's orbit was clear. Residuals about this smooth trend were observed and have been attributed to changes in the solar limb darkening function. Work on the understanding of this effect is proceeding at this time, both in theory and data analysis which involves further quantification of the systematic errors. It is anticipated that a measure of the solar flux will be developed from this analysis.

Theoretical work is also proceeding which will form the basis for interpretation of changes in the limb darkening function in terms of changes in flux. One paper on this topic is currently in the final stage of preparation (Hill and Logan 1983).

Development of the device which will provide the calibration of the telescope scale in the focal plane has progressed to the stage at which capital equipment will be ordered. The telescope itself is being modified to allow the easy incorporation of the optical grating which constitutes the heart of the calibration system. Although this device was not operational at the time and thus will have no effect on the 1981 data set, new data sets will have the calibration information available.

3. Conclusion

For the contract period indicated, many of the goals set for this project in previous reports have been accomplished. This primarily involves the demonstration that the SCLERA instrument can be used to monitor long-term variations in the solar diameter. This has been shown at both the scientific and administrative levels. The frozen mode of operation required for this program was new to this instrument and has

proved feasible. Although the unforeseen lightning damage reduced the actual amount of diameter data collected, it is anticipated that the existing 1981 data will yield some useful information about the use of solar diameter measurements as a probe of luminosity.

Appendix A

Evidence for Long-Term Variations in the Solar Limb Darkening Function; Implications towards Indirect Luminosity Diagnostics

T. P. Caudell, B. Beardsley, L. Yi, H. A. Hill, and R. J. Bos
Department of Physics, University of Arizona, Tucson, AZ

For many years now, it has been clear in the solar diameter measurements at SCLERA that changes in the extreme limb darkening function are responsible for most of the time varying signals. These are manifest through the properties of the FFTD edge definition and have time scales ranging from minutes to hours and to several days. A new set of measurements was taken in the early summer 1981, containing several unique advances over previous data sets, which provide further proof that these changes at the limb are observable and display significant variations over a time scale of several days. This was made possible by the implementation of a "white light" interferometer which yields a zero point fiducial against which the diameter measuring interferometer may be calibrated. Although this is not an absolute measurement of the solar diameter, it allows the long-term variations in diameter to be studied within a single data set. In addition, this new data set sampled seven equally spaced position angles from pole to pole, recording one diameter and six extreme-limb intensity profiles at each location. From this information, an average daily relative diameter was derived as well as three average daily measures of shape of the limb darkening function using off-line application of the FFTD with different aperture sizes. The relative diameters plotted against calendar date clearly display the geometric variation expected from the elliptical motion of the earth. When this and other major systematics are modeled and removed, variations of a large fraction of an arcsecond still remain. A linear correlation

was performed between these variations and the measures of changes in the limb darkening function. A high degree of correlation was found. Although a linear function is not the exact functional relation between these two quantities, the degree of correlation is sufficient to prove that significant variations in the observed relative diameter are produced by changes in the extreme limb darkening with several day time scales. Therefore extreme care must be taken when analyzing the solar diameter as an indirect diagnostic of luminosity, using models which do not include accurate treatment of the solar atmosphere. Conversely, monitoring the shape of the extreme limb darkening function will supply a sensitive measure of the atmospheric temperature gradient and therefore the solar flux.

This work was partially supported by the D.O.E. and N.A.S.A.

References

Caudell, T. P., Beardsley, B., Yi, L., Hill, H. A., and Bos, R. J. 1982, XVIII General Assembly of the International Astronomical Union, Patras, Greece, August 1982.

Gough, D. O. 1980, Nature, 288, 639.

Hill, H. A. 1978, The New Solar Physics, ed. J. A. Eddy (Westview Press, Boulder), p. 135.

Hill, H. A. 1981, NASA Final Report, "Solar Diameter Measurements for Study of Sun Climate Coupling," September 1981.

Hill, H. A., Stebbins, R. T. and Oleson, J. R. 1975, Astrophysical Journal, 200, 487.

Kandel, R., ed. 1981, Proceedings of workshop on "Sun and Climate," Toulouse, France, September 1980.

Oleson, J. R., Zanoni, C. A., Hill, H. A., Healy, A. W., Clayton, P. D., and Patz, D. L. 1974, Applied Optics, 13, 206.

Pepin, R. O., Eddy, J. A. and Merrill, R. B., eds. 1980, "The Ancient Sun," Proceedings of conference held in Boulder, Colorado, October 1979.

Sofia, S., O'Keefe, J., Lesh, J. R. and Endal, A. S. 1979, Science, 204, 1306.

White, O. R., ed. 1977, "The Solar Output and its Variation" (University of Colorado Press, Boulder).